

DOT/FAA/ND-97/12
Volume 4 of 9

Office of Communication,
Navigation, and Surveillance
Washington, DC 20591

Operation Heli-STAR - Helicopter Noise at Heliports

Krishan Ahuja
Robert Funk
Jeffrey Hsu
Charles Stancil

Georgia Tech Research Institute
Atlanta, Georgia 30332

September 1997

Final Report

This document is available to the public
through the National Technical Information
Service, Springfield, Virginia 22161.



U. S. Department
of Transportation

Federal Aviation
Administration

DISTRIBUTION STATEMENT A
Approved for Public Release
Distribution Unlimited

NOTICE

This document is disseminated under the sponsorship of the United States
Department of Transportation in the interest of information exchange.
The United States Government assumes no liability for the contents or use thereof.

Technical Report Documentation Page

1. Report No. DOT/FAA/ND-97/12 Volume 4 of 9	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Operation Heli-STAR - Helicopter Noise at Heliports		5. Report Date September 1997	
		6. Performing Organization No.	
7. Author (s) Krishan Ahuja, Robert Funk, Jeffrey Hsu, Marcie Benne, Mary L. Rivamonte, and Charles Stancil Georgia Tech Research Institute, Atlanta, Georgia, 30332		8. Performing Organization Report No. GTRI Report A5146-110/3	
9. Performing Organization Name and Address Under contract to: Science Applications International Corporation (SAIC) 1213 Jefferson Davis Highway, Suite 1500 Arlington, Virginia, 22202		10. Work Unit No. (TRAIS)	
		11. Contract or Grant No. DTFA01-93-C-00030, Task Order A3	
12. Sponsoring Agency Name and Address Federal Aviation Administration General Aviation and Vertical Flight Program Office, AND-710 800 Independence Avenue, S. W. Washington, DC 20591		13. Type Report and Period Covered Final Report	
		14. Sponsoring Agency Code AND-710	
15. Supplementary Notes AND-710 General Aviation and Vertical Flight Program Office			
16. Abstract Operation Heli-STAR (Helicopter Short-Haul Transportation and Aviation Research) was established and operated in Atlanta, Georgia, during the period of the 1996 Centennial Olympic Games. Heli-STAR had three major thrusts: 1) the establishment and operation of a helicopter-based cargo transportation system, 2) the management of low-altitude air traffic in the airspace of an urban area, and 3) the collection and analysis of research and development data associated with items 1 and 2. Heli-STAR was a cooperative industry/government program that included parcel package shippers and couriers in the Atlanta area, the helicopter industry, aviation electronics manufacturers, the Federal Aviation Administration (FAA), the National Aeronautics and Space Administration (NASA), and support contractors. Several detailed reports have been produced as a result of Operation Heli-STAR. These include 4 reports on acoustic measurements and associated analyses, and reports on the Heli-STAR tracking data including the data processing and retrieval system, the Heli-STAR cargo simulation, and the community response system. In addition, NASA's Advanced General Aviation Transport Experiments (AGATE) program has produced a report describing the Atlanta Communications Experiment (ACE) which produced the avionics and ground equipment using automatic dependent surveillance-broadcast (ADS-B) technology. This latter report is restricted to organizations belonging to NASA's AGATE industry consortium. A complete list of these reports is shown on the following page.			
17. Key Words Helicopter Rotorcraft Automatic Dependent Surveillance Heliport Datalink Community Involvement Security Short-Haul Transportation Helicopter Acoustics		18. Distribution Statement This document is available to the U. S. Public through the National Technical Information Service, 5258 Port Royal Road, Springfield, Virginia 22161.	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 54	22. Price

Operation Heli-STAR Technical Reports

Volume 1 DOT/FAA/ND-97/9	Operation Heli-STAR - Summary and Major Findings; S. Fisher, FAA AND-710, Washington DC and E. McConkey, Science Applications International Corporation, Arlington, Virginia; Principal Editors; September 1997
Volume 2 DOT/FAA/ND-97/10	Operation Heli-STAR - Helicopter Noise Levels Near Dekalb Peachtree Airport; Krishan Ahuja, Robert Funk, Jeffrey Hsu, Marcie Benne, Mary L. Rivamonte, and Charles Stancil; Georgia Tech Research Institute, Atlanta, Georgia; September 1997
Volume 3 DOT/FAA/ND-97/11	Operation Heli-STAR - Helicopter Noise Annoyance Near Dekalb Peachtree Airport; Krishan Ahuja, Marcie Benne, Mary L. Rivamonte, Robert Funk, Jeffrey Hsu, and Charles Stancil; Georgia Tech Research Institute, Atlanta, Georgia; September 1997
Volume 4 DOT/FAA/ND-97/12	Operation Heli-STAR - Helicopter Noise at Heliports; Krishan Ahuja, Robert Funk, Jeffrey Hsu, and Charles Stancil; Georgia Tech Research Institute, Atlanta, Georgia; September 1997
Volume 5 DOT/FAA/ND-97/13	Operation Heli-STAR - Effects of Buildings on Helicopter Noise; Krishan Ahuja, Robert Funk, Jeffrey Hsu, Michael Heiges, and Charles Stancil; Georgia Tech Research Institute, Atlanta, Georgia; September 1997
Volume 6 DOT/FAA/ND-97/14	Operation Heli-STAR - Aircraft Position Data; Michael Heiges, Shabnam Khan; Georgia Tech Research Institute, Atlanta, Georgia, September 1997
Volume 7 DOT/FAA/ND-97/15	Operation Heli-STAR - Cargo Simulation System; Ellen Bass, and Chasles Stancil; Georgia Tech Research Institute, Atlanta, Georgia, September 1997
Volume 8 DOT/FAA/ND-97/16	Operation Heli-STAR - Community Involvement; Christine Eberhard and Bobbi Rupp; CommuniQuest, Inc., Manhattan Beach, California; September 1997
Volume 9 DOT/FAA/ND-97/17	Operation Heli-STAR - Atlanta Communication Experiment (ACE), AGATE Flight Systems Communication Work Package 1.4, (AGATE Restricted Information) (AGATE Flight Systems Communication Team), December 1996.

FOREWORD

This is Volume 4 of a 9-volume report documenting the activities and results of Operation Heli-STAR, the Atlanta Short-Haul Transportation System (ASTS). ASTS was a cooperative government/industry program that established a helicopter transportation system to support community of Atlanta during the 1996 Olympic games. Volumes 2 through 5 of this set of reports documents the noise studies that were performed during Operation Heli-STAR. The noise research was performed by Georgia Tech Research Institute (GTRI). GTRI also produced two additional reports documenting Operation Heli-STAR. Volume 6 describes the aircraft position data processing research, and Volume 7 documents a Cargo Simulation System that was used in support of Heli-STAR cargo operations. The research and development elements of Operation Heli-STAR were funded by the Federal Aviation Administration through Science Applications International Corporation (SAIC).

The GTRI manager of the overall ASTS program was Mr. C. Stancil. The Principal Investigator of the noise studies, reported in volumes 2 through 5, was Dr. K. K. Ahuja of GTRI. GTRI personnel responsible for making and analyzing day-to-day noise measurements were Dr. R. Funk and Mr. Jeff Hsu who were assisted by a team of 20 researchers. Ms. Marcie Benne, a graduate student from the School of Psychology lead the effort on the community survey reported in Volume 2. She was assisted by Ms. Mary Lynn Rivamonte, a student in the School of Aerospace Engineering. The authors are particularly grateful for Dr. Mike Heiges of GTRI for providing the helicopter altitudes and flight paths and to Mr. Stephen Williams, also of GTRI, for setting up the microphone locations for noise contour measurements.

The titles of the four volumes reporting noise research are:

Volume 2 - Helicopter Noise Levels Near Dekalb Peachtree Airport

Volume 3 - Helicopter Noise Annoyance Near Dekalb Peachtree Airport

Volume 4 - Helicopter Noise at Heliports

Volume 5 - Effects of Buildings on Helicopter Noise

The titles of the other two volumes authored by GTRI are:

Volume 6 - Aircraft Position Data

Volume 7 - Cargo Simulation System

TABLE OF CONTENTS

SECTION	TITLE	PAGE
EXECUTIVE SUMMARY		viii
1.0 OBJECTIVE		1
2.0 BACKGROUND		3
2.1 Introduction to Noise Metrics		3
2.1.1 Sound pressure level		3
2.1.2 A-weighted sound pressure level		4
2.1.3 Equivalent continuous sound level		4
2.1.4 Day-Night average sound level		5
3.0 TEST SETUP AND DATA ANALYSIS		9
3.1 Selection of Heliport Locations		9
3.1.1 Galleria (GAL)		9
3.1.2 Georgia Baptist Hospital (GBH)		11
3.1.3 North Fulton County Hospital (RAF)		12
3.2 Measurement During Cargo Operations		13
3.2.1 Measurement equipment overview		13
3.2.2 Operation and parameters measured		14
3.2.3 Data reduction methodology		15
4.0 RESULTS AND DISCUSSION		17
4.1 Repeatability of helicopter flight activities		17
4.1.1 Repeated helicopter (N724MB) at the same helipad site (GAL)		17
4.1.2 Repeated helicopter type (BO-105) at the same helipad site (GAL)		18
4.1.3 Summary		19
4.2 Effect of helipad surroundings		19
4.2.1 Comparative results of the preliminary study		19
4.2.2 Summary of the preliminary study		21

LIST OF TABLES

TABLE	TITLE	PAGE
3.1....Flight schedule at Galleria (GAL) helipad for 1 August 1996	10	
3.2....Flight schedule at Georgia Baptist Hospital (GBH) helipad for 1 August 1996	12	
3.3....Flight schedule at North Fulton County Hospital (RAF) helipad for 1 August 1996	13	
4.1....The predicted DNL level at different measurement locations at GAL site.....	18	
4.2....The predicted DNL level at different measurement locations at GAL site for different helicopters	19	

LIST OF FIGURES

FIGURE	TITLE	PAGE
3.1	Aerial photograph of Galleria helipad (GAL) and its surrounding area	23
3.2	A map of the Galleria helipad and the immediate surrounding area.....	24
3.3	The acoustic measurement locations at the Galleria helipad site.....	25
3.4	Aerial photograph of Georgia Baptist Hospital helipad (GBH) and its surrounding area.....	26
3.5	A map of Georgia Baptist Hospital and the immediate surrounding area	27
3.6	The acoustic measurement locations at Georgia Baptist Hospital helipad site.....	28
3.7	Aerial photograph of North Fulton County Hospital helipad (RAF) and its surrounding area	29
3.8	A map of North Fulton County Hospital helipad and the acoustic measurement location at this helipad site	30
4.1	100 ms Leq acquired at Galleria helipad for flight A28 and A38 (Measurement location: underneath flight path, 100 ft away from the landing point; Helicopter: N724MB, BO-105)	31
4.2	100 ms Leq acquired at Galleria helipad for flight A28 and A38 (Measurement location: 50 ft. to the left of the helipad. Helicopter: N724MB, BO-105)	32
4.3	100 ms Leq acquired at Galleria helipad for flight A28 and A38 (Measurement location: 50 ft. to the right of the helipad. Helicopter: N724MB, BO-105)	33
4.4	100 ms Leq acquired at Galleria helipad for flight A28 and A38 (Measurement location: 50 ft. to the right of the helipad. Helicopter: N724MB, BO-105)	34
4.5	100 ms Leq acquired at Galleria helipad for flight A28 and A38 (Measurement location: underneath flight path, 100 ft away from the landing point; Helicopter: N724MB, BO-105)	35
4.6	100 ms Leq acquired at Galleria helipad for flight A28 and A38 (Measurement location: 50 ft. to the left of the helipad. Helicopter: N724MB, BO-105)	36

4.7	100 ms Leq acquired at Galleria helipad for flight A28 and C33 (Measurement location: underneath flight path, 100 ft away from the landing point; Helicopter: N724MB, N54197)	37
4.8	100 ms Leq acquired at Galleria helipad for flight A28 and B38 (Measurement location: underneath flight path, 100 ft away from the landing point; Helicopter: N724MB, N54197)	38
4.9	100 ms Leq acquired at Galleria helipad for flight A28 and C33 (Measurement location: underneath flight path, 100 ft away from the landing point; Helicopter: N724MB, N54197)	39
4.10	100 ms Leq acquired at Galleria helipad for flight A28 and B38 (Measurement location: underneath flight path, 100 ft away from the landing point; Helicopter: N724MB, N721MB)	40
4.11	100 ms Leq acquired at three different helipad sites (Measurement location: underneath flight path, 100 ft away from the landing point; Helicopter: N721MB, BO-105)	41
4.12	100 ms Leq acquired at three different helipad sites (Measurement location: underneath flight path, 100 ft away from the landing point; Helicopter: N721MB, BO-105)	42

EXECUTIVE SUMMARY

During Project Heli-STAR, acoustic measurements were performed to assess the effect of various helipad surroundings on the noise due to helicopter flights. Three helipad sites were selected; Galleria (GAL), Georgia Baptist Hospital (GBH), and North Fulton Regional Hospital (RAF). Each had distinct features. The Galleria pad was in the open with no nearby buildings. The helipad at Georgia Baptist Hospital was located next to the hospital building. The North Fulton Regional Hospital pad was located on top of a parking garage.

The repeatability of Leq traces was examined for the same helicopter in multiple operations at the same helipad and multiple operations of the same helicopter type at the same helipad to determine if a single flight could be used to predict a metric like DNL. The peak values of Leq measured during takeoff and landing correlated well and provided DNL values within 1 dB of each other.

One helicopter made stops at all three helipads during the measurements. The noise levels for this helicopter were examined at each of the helipads for a measurement location 100 feet from the helipad along the flight path. Compared to the Galleria site, GBH had a slightly higher predicted DNL due to acoustic reflections from the surrounding buildings. Measurements at RAF indicated a much lower level due to the measurement location being on the ground below the parking deck and the shielding provided by the parking deck when the helicopter was on the pad.

SECTION 1

OBJECTIVE

The objective of this study was to compare the noise associated with scheduled helicopter cargo operations at selected helipad sites with emphasis on the effect of the helipad surroundings. The specific objectives were to check the repeatability of measured noise levels for multiple operations at a single helipad and to measure and compare noise levels of flights of the same helicopter at different helipads. The acoustic data was logged by sound level meters. A data reduction methodology was designed and implemented to facilitate the comparison of the effect of the helipad surroundings on the measured noise level.

SECTION 2

BACKGROUND

2.1 Introduction to Noise Metrics

An introduction to the noise metrics used in this document is included here. The acoustical metrics described here are sound pressure level (dB), A-weighted sound pressure level (dBA), equivalent continuous sound level (L_{eq}), and day-night average sound level (DNL).

2.1.1 Sound pressure level

Sound is transmitted through the air by sound waves which are small oscillations in pressure. Impingement of these pressure oscillations on the ear produce the sound we hear. The sound waves can be characterized by two properties: the frequency of oscillation, measured in Hertz (Hz) and the sound pressure level measured in decibels (dB).

Sound pressure level is a ratio of the sound pressure of a source to a reference pressure. The reference pressure is 20 micropascals, the threshold of hearing. Decibels are a logarithmic scale of sound pressure level. The normal range of sound pressure levels encountered is from about 30 dB to 100 dB in everyday sounds.

It is important to stress the logarithmic nature of the sound pressure level. This prevents using simple addition when summing noise levels. For instance, if two noise sources each produce 100 dB individually, when operated together they don't produce 200 dB but 103 dB. Each doubling of the noise results in a 3 dB increase in the total. This also comes into play when adding sources when one is much higher than the other. If an 80 dB source and a 100 dB source are operated together the resulting level would still be 100 dB. The louder source masks the quieter one. This holds true for sources with more than 12 dB difference.

2.1.2 A-weighted sound pressure level

An important characteristic of sound is its frequency. This is the rate at which sound pressure fluctuations are sensed by the ear. It is expressed in cycles per second or Hertz (Hz). The normal frequency range of hearing for most people extends from a low frequency of about 20 Hz to a high frequency between 10 and 15 kHz. But the sensitivity to these frequencies is not uniform. People are most sensitive to frequencies in the range of normal conversation, typically from 1000 to 2000 Hz. People are much less sensitive to lower frequencies and somewhat less sensitive to higher frequencies. A filter, called an A-weighting filter, is used to weight different frequencies according to the sensitivity of the human ear at those frequencies. The relative response of this filter over the audible range is shown in Figure 2.1. This filter is applied to the linear output of a microphone system to more accurately reflect the level of the sound sensed by the human ear. Because this filter generally matches the sensitivity of the human ear, sounds having higher A-weighted sound levels are judged to be louder than those with lower A-weighted sound levels, a relationship which might not otherwise be true. It is for this reason that A-weighted sound levels are normally used to evaluate environmental noise sources.

Because of the correlation with human hearing, the A-weighted sound pressure level has been adopted as the basic measure of environmental noise by the Environmental Protection Agency (EPA).

2.1.3 Equivalent continuous sound level

The sound pressure level is an instantaneous measure of the noise level that varies with time. The Equivalent Continuous Sound Level, abbreviated Leq, is a measure of the exposure resulting from the accumulation of sound levels over a particular period of interest -- for example, a minute, an hour, or a full 24-hour day. The sound levels may be weighted and normally, for environmental measurements, A-weighting is used. Because the length of the period can be different depending on the time frame of interest, the applicable period

should always be identified or clearly understood when discussing the metric. Such durations are here represented as $Leq_{(1min)}$. The environmental mode used on the sound level meters employed in this study was able to log 1 minute or 1 second Leq's. The FASTORE mode available on the sound level meters allowed recording Leq's for times as short as 10 ms.

Conceptually, Leq may be thought of as a constant sound level over the period of interest that contains as much sound energy as the actual time-varying sound level with its normal peaks and valleys. It is important to note, that, if heard, the two signals (the constant one and the time-varying one) would sound very different from each other. Also, recalling the previous description of the addition of sound levels, be aware that the "average" sound level suggested by Leq is not an arithmetic mean, but a logarithmic, or "energy-averaged" sound level. Comparable to the addition of decibels, this means that higher A-weighted sound levels receive greater emphasis than lower values. For example, if the sound level is 50 dBA for 30 minutes, followed by 100 dBA for the next 30 minutes, then the Leq for the entire hour is 97 dBA -- not the 75 dBA that we might expect. Thus, loud events clearly dominate any noise environment described by the metric.

2.1.4 Day-Night average sound level

The Day-Night Sound Level (DNL) represents a concept of noise average as it occurs over a 24-hour period. It is a metric developed by the EPA to account for the greater annoyance of noise when people are sleeping. It is much like a 24-hour Leq with the important exception being that the DNL treats nighttime noise differently than daytime noise. In determining DNL, it is assumed that the A-weighted levels occurring at night (defined very specifically as 2200 to 0700) are 10 decibels louder than they really are. This 10-dB penalty is applied to account for greater sensitivity to nighttime noise, plus the fact that events at night are often more intrusive because nighttime ambient noise is less

Computed values of DNL are often depicted as noise contours reflecting lines of equal exposure around an airport (much as topographic maps indicate contours of equal elevation). The contours usually reflect long-term (annual average) operating conditions, taking into account the average flights per day, how often each runway is used throughout the year, and where over the surrounding communities the aircraft normally fly. Alternative time frames representing a single day or a typical seasonal day are also helpful in understanding shorter term aspects of a noise environment. In this study, DNL values were calculated from measurements over periods of one day or less in order to assess the effect of large activity level changes.

Representative values of DNL in our environment range from a low of 40 to 45 decibels in extremely quiet, isolated locations, to highs of 80 or 85 decibels immediately adjacent to a busy truck route or off the end of a runway at an active Air Force base. More typical values would be in the range of 50 or 55 decibels for a quiet residential community to 60 or 65 decibels in an urban residential neighborhood.

Why is DNL used to describe noise around airports? The U.S. Environmental Protection Agency identified the measure as the most appropriate means of evaluating airport noise based on the following considerations:

1. The measure should be applicable to the evaluation of pervasive long-term noise in various defined areas and under various conditions over long periods of time.
2. The measure should correlate well with known effects of the noise environment and on individuals and the public.
3. The measure should be simple, practical and accurate. In principal, it should be useful for planning as well as for enforcement or monitoring purposes.
4. The required measurement equipment, with standard characteristics, should be commercially available.
5. The measure should be closely related to existing methods currently in use.
6. The single measure of noise at a given location should be predictable, within an acceptable tolerance, from knowledge of the physical events producing the noise.

7. The measure should lend itself to small, simple monitors which can be left unattended in public areas for long periods of time.

Now most other public agencies dealing with noise exposure, including the Federal Aviation Administration (FAA), the Department of Defense, and the Department of Housing and Urban Development (HUD), also have adopted DNL in their guidelines and regulations. Generally, the regulations require that homes and schools be outside the 65 DNL contour, and light industrial operations occur in areas with up to 70 DNL.

SECTION 3

TEST SETUP AND DATA ANALYSIS

3.1 Selection of Heliport Locations

Among the helipad sites used in the Helicopter Short-Haul Transportation and Aviation Research (Heli-STAR) program, three helipad sites, Galleria (GAL), Georgia Baptist Hospital (GBH), and North Fulton County Hospital (RAF) were selected for their distinct surrounding features. At each selected helipad site, based upon the surrounding terrain constraints, four to five noise measurement locations were selected with at least one common measurement location, relative to the pad location and helicopter approach path, at all three sites. Detailed descriptions of the selected helipads and the test setup at each helipad site follow.

3.1.1 Galleria(GAL)

The helipad was located near the intersection of interstate highways I-285 and I-75 in the northwest Metro Atlanta area. A photograph of this helipad and its surrounding area is shown in Figure 3.1. As presented in the photograph, the helipad was located on the top of a plateau. The south side of the helipad was neighboring a commercial development and a busy street (Akers Mill Rd.) and in the distance to the west of the helipad was a zone of business and office buildings. Facing these two directions, the helipad was partially enclosed by a patch of dense shrubs and sparsely populated tall vegetation. On the north and the east side of the helipad, the area was open where the edge of the plateau rolled steeply down to the adjacent interstate highway and on-ramps. To the immediate west of the plateau, the edge of the plateau fell down to a deep ravine. The area within 1000 feet diameter surrounding the helipad was free of any hard acoustic reflective surfaces. The prescribed helicopter approach and departure path was from the helipad heading northwest to the interstate highway and the helicopter traffic flight path roughly coincided with the interstate highway. A map of the

helipad and the immediate surrounding area is presented in Figure 3.2 showing the prescribed helicopter flight path and the noise measurement locations.

Based upon the primary objective of the study and terrain limitation, five measurement locations were selected near the helipad as illustrated in Figure 3.2. One of the measurement locations was positioned underneath the approaching and departing flight path, 100 feet away from the center of the helipad and this was the common relative measurement location among all three helipad sites. Two other measurement locations were located 50 feet away from the center of the helipad on the left and the right of the centerline of the approach path facing the helipad. Another location was located 100 feet beyond the helipad on the centerline of the approach path facing the helipad. These four measurement locations provided noise measurements in the near field range around the helipad. One additional location in the far field range was chosen to be 200 feet away from the center of the helipad based on the terrain limitation. The measurement locations are labeled on Figure 3.3, an enlarged illustration of the previous figure.

Six flights of a BO-105 helicopter for cargo operations were scheduled for 1 August 1996 to be operating to and from Galleria helipad. The flight schedule and the tail number of each helicopter is listed in Table 3.1.

Table 3.1 Flight schedule at Galleria (GAL) helipad for 1 August 1996

GAL			
Tail Number	Flight Number	Arrival Time	Departure Time
N54197	C23	13:16	13:22
N724MB	A28	13:48	13:55
N54197	C26	14:20	14:25
N54197	C33	16:10	16:15
N724MB	A38	16:40	16:47
N7212MB	B38	16:57	17:04

3.1.2 Georgia Baptist Hospital (GBH)

The helipad was located on the premises of Georgia Baptist Hospital on the east side of downtown Atlanta. The photograph of this helipad indicating its location in relation to the surrounding hospital buildings and its relative position to the city landscape is shown in Figure 3.4. As illustrated in this figure, this ground level helipad was positioned next to a series of hospital buildings located on the east side of the helipad. The hospital buildings provided large acoustic reflecting surfaces. The south and the west sides of the helipad were open to parking spaces. The surface of the helipad was roughly 6 feet above the plane of the parking lot surface. Separating the parking area on the south from the helipad was a row of hedges wedged between a short wall on the edge of the parking lot and the rising plateau where the helipad resided. The parking area to the west of the helipad was across the street from the helipad. The traffic in the parking lot and on the street was light. The area north of the helipad was occupied by a small, grassy courtyard and the hospital entrance ramp. The prescribed approach and departure path for helicopter operations was from south of the helipad over the parking area. A map of the helipad and the immediate surrounding area is presented in Figure 3.5 showing the prescribed helicopter flight path and the noise measurement locations.

Four measurement locations were selected on this helipad site as illustrated in Figure 3.5. An attempt was made to establish the same relative measurement locations as those in the Galleria helipad site. However, due to the constraints of the surroundings and the issue of personnel safety (i.e. to avoid placing measurement locations within the ground traffic path), the measurement locations were selected to be as close to those in the Galleria site as possible. The common measurement location directly underneath the approaching and departing flight path, about 100 feet away from the center of the helipad helicopter landing point, was situated in the parking lot south of the helipad. Extending the flight path to the north of the helipad, about 88 feet away from the center of the helipad landing point, a

measurement location was chosen, located on the edge of the grassy courtyard next to the hospital entrance ramp. The closest location east of the helicopter landing point where measurement equipment can be secured, was 69 feet away from the center of the landing point on the edge of the helipad. The fourth measurement location was selected to be 107 feet west of the helicopter landing point across the street from the helipad on the edge of the parking lot. The measurement locations are labeled on Figure 3.6, an enlarged illustration of the previous figure.

Two flights of BO-105 helicopters for cargo operations were scheduled for 1 August 1996 to be operating from the GBH helipad. The flight schedule and the tail number of each helicopter is listed in Table 3.2.

Table 3.2 Flight schedule at Georgia Baptist Hospital (GBH) helipad for 1 August 1996

GBH			
Tail Number	Flight Number	Arrival Time	Departure Time
N721MB	B27	13:58	14:05
N724MB	A37	16:26	16:33

3.1.3 North Fulton County Hospital (RAF)

The helipad was located on the premises of North Fulton County Regional Hospital in the northern metro Atlanta area. A photograph of this helipad site and its surrounding area is shown in Figure 3.7. As presented in the photograph, the helipad was located on the top of the parking garage adjacent to the hospital. With the helipad located on a highly elevated location, very little surrounding acoustic reflecting surfaces were present except for a small building containing elevator equipment next to the helipad. The approach and departure path for helicopter operations and the measurement locations are shown in Figure 3.8.

Five measurement locations were selected at this helipad site as illustrated in Figure 3.8. The common measurement location directly underneath the approaching and departing flight path for helicopter cargo flight operations, about 100 feet away from the helicopter landing point, was situated on the grassy field about 50 feet below the top surface of the parking garage where the helipad resided. Along the flight path, two more measurement locations were selected in the near field range. One of the measurement locations was located underneath the flight path 50 feet away from the helicopter landing point and the other measurement location was located 50 feet past the helicopter landing point along the line of the approach and departure path. A location in the far field range was also selected to be 250 feet away from the helicopter landing point directly underneath the flight path. One additional measurement location was placed about 110 feet away from the helicopter landing point directly underneath the VASI approach path.

Two flights of BO-105 helicopters for cargo operations were scheduled for 1 August 1996 to be operating from the RAF helipad. The flight schedule and the tail number of each helicopter is listed in Table 3.3.

Table 3.3 Flight schedule at North Fulton County Hospital (RAF) helipad for 1 August 1996

RAF			
Tail Number	Flight Number	Arrival Time	Departure Time
N721MB	B29	14:19	14:26
N721MB	B39	17:14	17:21

3.2 Measurement during cargo operations

3.2.1 Measurement equipment overview

The outdoor acoustic measurements envisioned for this program dictated a portable, battery-powered, weather-resistant unit. Additionally, the ability to log Leq values for computation of DNL was required. This was accomplished with portable sound level monitoring setups. Each setup consisted of a sound level meter and battery pack in a waterproof case and a tripod with a wind screen and rain protection for the microphone. A digital audio tape (DAT) recorder was supplied to enable recording of raw data.

Each noise measurement setup consisted of the following components:

- CEL Type 1 Sound Level Analyzer Model 573 or 593
- CEL-527 Preamplifier
- CEL-250 Type 1, 1/2" Electret microphone
- Sony TCD-D8 DAT tape recorder
- CEL-284/2 Type 1 acoustic calibrator
- 5 meter microphone extension cable
- CEL-594 wind and rain protection system for microphone
- tripod
- rechargeable battery
- weather-resistant case

Three types of meters were being used: CEL-573.A1, CEL-573.C1, and CEL-593.C1.

All meters had A and C weighting filters. The CEL-573.C1 and CEL-593.C1 also included octave and third octave filters. Figure 3.9 shows a meter setup. The microphone and preamplifier were mounted on a tripod and protected by wind and rain gear.

3.2.2 Operation and parameters measured.

All SLM's had the ability to log Leq values with time intervals of less than one second with one frequency weighting selected. The meters also contained internal clocks for

time stamping. For all tests in this study, the SLM's were setup to measure Leq values over a 100 ms interval with A-weighting. The recorded Leq values were tagged with a time of day based on a clock internal to the SLM. All noise data were also recorded on DAT

Operationally the meters were run as follows:

1. All meter clocks were synchronized.
2. The equipment was setup at the assigned location. The microphone was mounted five feet from the ground and SLM case was moved away from the microphone location to minimize interference.
3. A calibrator was used to calibrate the SLM; the calibration signal recorded on DAT.
4. The SLM was set to log the values of $Leq_{(100\ ms)}$ with both A-weighting and linear-weighting.
5. The SLM was set to start the acquisition and DAT recoder manually prior to the arrival of helicopters.
6. The SLM was checked periodically during the acquisition to ensure correct operation of the equipment.

7. Activity around the test location was recorded on log sheets by the test personnel, noting any abnormal occurrences and all corresponding noise events.
8. Landing and departing time of each helicopter flight was recorded on log sheets by the test personnel.
9. The calibration of the equipment was checked at the conclusion of the acquisition and any deviation noted on the log sheet and the end calibration was recorded on DAT.

3.2.3 Data reduction methodology

For the purpose of quantifying the noise effect at each helipad site with different scheduled helicopter flights, the predicted DNL level for each helicopter flight is calculated for an assumed condition with the following methodology.

For each scheduled helicopter flight at a given helipad, the flight activity is segmented into three different event sections: 1) approach and landing, 2) ground idling, and 3) throttling up, lifting off and departing. In this study, the 100 ms Leq was acquired at each measurement location. By logarithmically averaging the 100 ms Leq values within each segment of the time period, the Leq values for the duration of each flight event section can be obtained.

If the Leq values for each flight event were presented in conjunction with additional information regarding the frequency of the scheduled flight, the time duration of each flight event, and the ambient noise level at both day time and night time periods, as defined in the previous section, then the DNL level at the measurement location can then be predicted for the given flight activities with their surrounding ambient noise conditions.

To compare the effect of the helipad surroundings with each helicopter flight, the DNL level was predicted at each measurement location for a given helipad having 24 scheduled identical flights during the day-time period with each flight having 5 minutes of ground idling time. The ambient condition was assumed to be 50 dBA during the day-time period and 45 dBA during the night-time period.

SECTION 4

RESULTS AND DISCUSSION

4.1 Repeatability of helicopter flight activities

4.1.1 Repeated helicopter (N724MB) at the same helipad site (GAL).

At the Galleria helipad site, on 1 August 1996, the BO-105 cargo helicopter with tail number N724MB was scheduled at 1348 and 1640 with variation in helicopter weight due to differences in fuel burned and the contents of the cargo. Data were acquired for these two flights at all five measurement locations. Figure 4.1 shows the 100 ms Leq traces seen at the location 100 feet away from the center of the helipad underneath the flight path, for both flights A28 and A38 landing at the Galleria helipad with the time scale shifted to be zero at the time of the touchdown. As shown in this plot, the Leq traces fall almost right on top of each other. Similar results, as shown in Figures 4.2 and 4.3, were also obtained at the locations left and right of the approaching flight path facing the helipad 50 feet away from the center of the helipad.

Upon departing the helipad, since the departure path was the same as the approach path, the helicopter had to be turned around immediately after it had lifted-off from the ground and hovered briefly before departing. This maneuver resulted in some discrepancy in the Leq trace results obtained at the measurement locations. Figure 4.4 shows the 100 ms Leq traces obtained at the location 50 feet away from the center of the helipad to the right of the flight path. As indicated in this plot, with time scale set to zero at the time of lift-off, the throttle up time for these two flights was different by more than ten seconds. Immediately after lift-off from the ground, the helicopter was turned around and this was indicated by an increasing noise level in the measured Leq traces as the tail of the helicopter passed by. Prior to departure, flight A38 spent more than ten additional seconds hovering as illustrated in this

figure. Similar data were also obtained at the location underneath the flight path 100 feet away and the location 50 feet away to the left of the helipad as shown in Figures 4.5 and 4.6.

Despite the fact that some differences were observed in the Leq traces associated with the event of helicopter departure, the predicted DNL levels were nonetheless similar. Based on the 100 ms Leq values obtained at each measurement location, the predicted DNL level for both flights using the methodology and condition presented in the previous section are presented in Table 4.1. As shown in this table, the DNL levels predicted were within 1 dB of each other. In terms of contribution to DNL level at each measurement location, these two helicopter flight were seemingly identical.

Table 4.1 The predicted DNL level at different measurement locations at GAL site.

Flight	Locations				
	C100	R0-50	L0-50	C(-100)	R0-200
A28	76.0 (dBA)	67.0 (dBA)	84.2 (dBA)	82.8 (dBA)	74.2 (dBA)
A38	76.5 (dBA)	66.4 (dBA)	84.3 (dBA)	82.9 (dBA)	73.7 (dBA)

4.1.2 Repeated helicopter type (BO-105) at the same helipad site (GAL).

The acoustic data for two other BO-105 cargo flights, C33 and B38, scheduled for the Galleria helipad, were also analyzed from the acquired data. As presented in Figures 4.7 and 4.8, the $Leq_{(100\text{ ms})}$ traces obtained at the measurement location 100 feet away from the center of the helipad underneath the flight path illustrated that even with a physically different helicopter and pilot in addition to differences in the weight of the helicopter, Leq traces for the approaching and landing of the helicopters were very similar for all four BO-105 flights.

The differences between the $Leq_{(100\text{ ms})}$ traces associated with helicopter departure events for flights C33 and B38 in reference to flight A28 were also evident as shown in Figure 4.9 and 4.10. However, since the maximum noise levels for each flight during the departure event which strongly influence the Leq value for the duration of the departure

event, were similar, the predicted DNL value based on each of these four flights at each measurement location was also similar. Table 4.2 summarizes the predicted DNL values based on each of these four flights at all five measurement locations. The differences between the DNL level predicted at each measurement location were within 2 dB of each other. The measurement location that was on the centerline of the approaching flight path, 100 feet beyond the center of the helipad, was least sensitive to the variation of flight maneuvers during landing and take-off.

Table 4.2 The predicted DNL level at different measurement locations at GAL site for different helicopters

	Locations				
GAL	C100	R0-50	L0-50	C(-100)	R0-200
A28	76.0 (dBA)	67.0 (dBA)	84.2 (dBA)	82.8 (dBA)	74.2 (dBA)
C33	76.7 (dBA)	65.6 (dBA)	83.3 (dBA)	83.4 (dBA)	74.5 (dBA)
A38	76.5 (dBA)	66.4 (dBA)	84.3 (dBA)	82.9 (dBA)	73.7 (dBA)
B38	75.0 (dBA)	65.4 (dBA)	83.2 (dBA)	81.6 (dBA)	74.5 (dBA)

4.1.3 Summary

In this portion of the preliminary study, the results indicated that with physically the same helicopter, the Leq traces obtained at the same measurement location were nearly identical with each repeated flight except during the helicopter departure event. The results also indicated that with the same type of helicopter, the similarity in the Leq traces were within reasonable range with the exception of the flight departure event. The predicted DNL levels for the same helicopter type were similar at each measurement location despite the fact that differences were observed during the departure event. The results suggested that in our study, the Leq traces for helicopter approach, landing and ground idling along with the predicted DNL values can be used to gauge the effect of the helipad surroundings.

4.2 Effects of helipad surroundings

4.2.1 Comparative results of the preliminary study

In this preliminary study, among all the scheduled cargo flights on 1 August 1996, one BO-105 cargo helicopter, N721MB, was scheduled to be at all three selected helipad sites. The common measurement location is positioned at 100 feet away from the center of the helipad directly underneath the flight path. The gross weight of the helicopter was not exactly the same at each selected helipad due to fuel burned and differences in cargo contents. However, from the results obtained in the previous section, differences in the gross weight of the helicopter did not seem to have significant impact on the Leq measurements of the helicopter noise. The $Leq_{(100ms)}$ traces for approach and landing are presented in Figure 4.11 and the $Leq_{(100ms)}$ traces for departure are shown in Figure 4.12. As illustrated in Figure 4.11, the difference between the Leq traces acquired from Georgia Baptist Hospital helipad and Galleria Helipad were small, but the Leq trace obtained at North Fulton County Hospital helipad had significantly lower levels than the data obtained from the other two locations. When the helicopter first appeared near the helipad area and helicopter noise rose above the ambient level at the Georgia Baptist Hospital helipad location, significant amounts of acoustic reflection were observed in the Leq trace. On approach, while the helicopter was passing over the common measurement location, among the data acquired at all three helipad sites, the Leq trace recorded at the GBH site showed the highest values that can be attributed to the acoustic reflection of the series of hospital buildings. The lowest Leq value was recorded at the RAF site where the actual distance from the helicopter to the SLM was the greatest, due to the helipad location being on top of the parking deck.

From the time the helicopter gradually approached the landing point until the helicopter touched down and entered the ground idling stage, the noise level at the RAF site was dropping significantly in comparison to the data observed at the other two sites. While the helicopter was in the ground idling stage, at both the GBH and GAL sites, there was a direct line of sight between the measurement SLM and the helicopter, however, at the RAF site, since the helipad was on the top of the parking garage, about 50 feet above the SLM and 60 feet away from the edge of the roof, there was no direct line of sight between the measurement equipment and the helicopter. Portions of the parking deck rooftop were providing acoustic shielding with respect to the location where the SLM resided. Upon

departing the helipad, during helicopter lift-off and turn around, at the GBH site, additional helicopter noise was again observed due to acoustic reflection from nearby hospital buildings.

Based on the Leq traces acquired, DNL levels predicted for 24 daytime flights with an assumed ground idling time of 5 minutes were 77.7 dBA at the GBH site, 76 dBA at the GAL site and 68.9 dBA at the RAF site. The findings with DNL predictions coincide with the results observed in measured Leq traces.

4.2.2 Summary of the preliminary study

Noise levels and DNL levels increased marginally when the helipad was near large buildings which provided large acoustic reflecting surfaces. The resultant increases can be seen in both Leq traces and also in predicted DNL levels. Noise levels were significantly reduced when the helipad was on top of a building or structure which had reasonable elevation and a building footprint so that a portion of the building roof was providing acoustic shielding.



Figure 3.1 Aerial photograph of Galleria helipad (GAL) and its surrounding area.

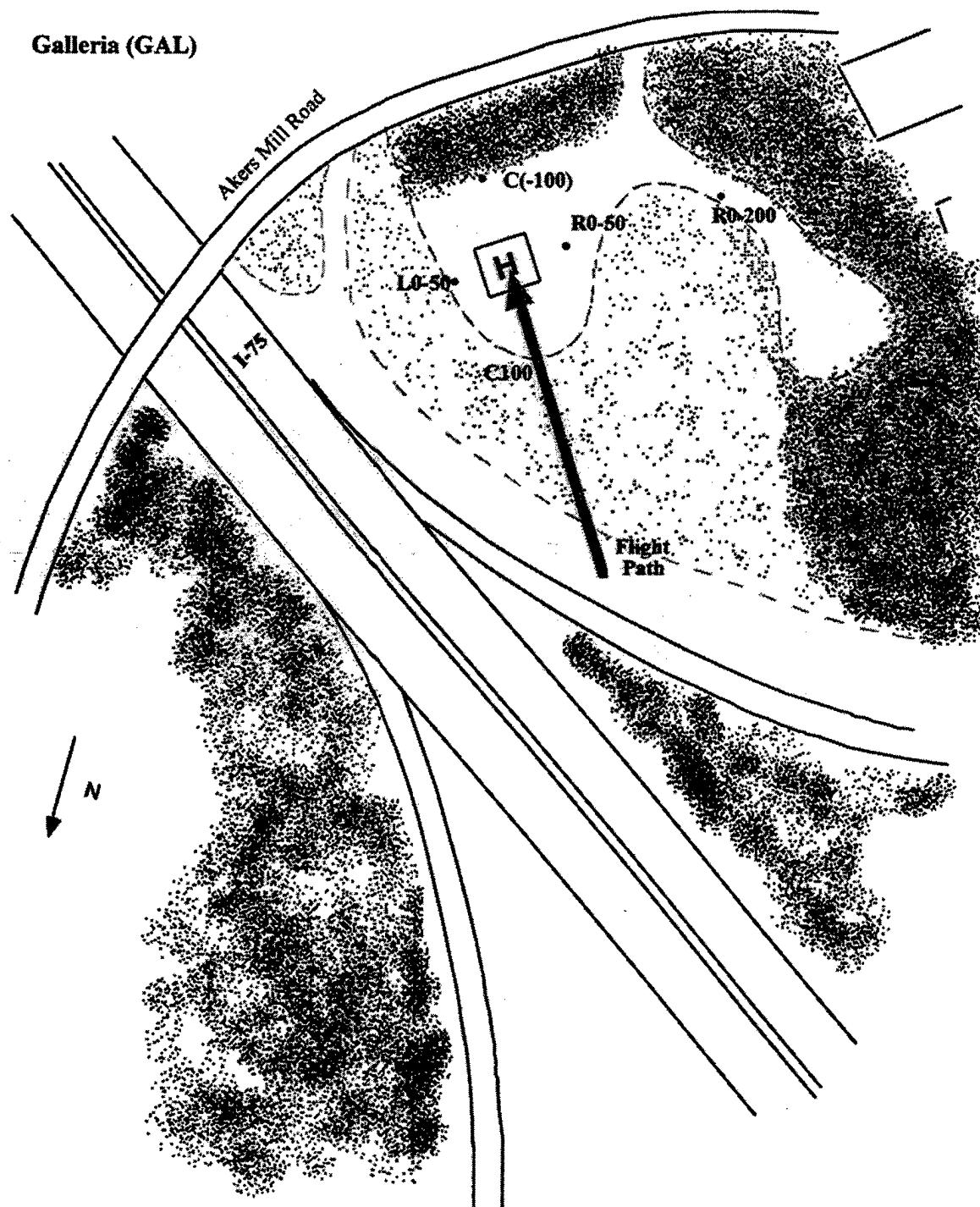


Figure 3.2 A map of the Galleria helipad and the immediate surrounding area.

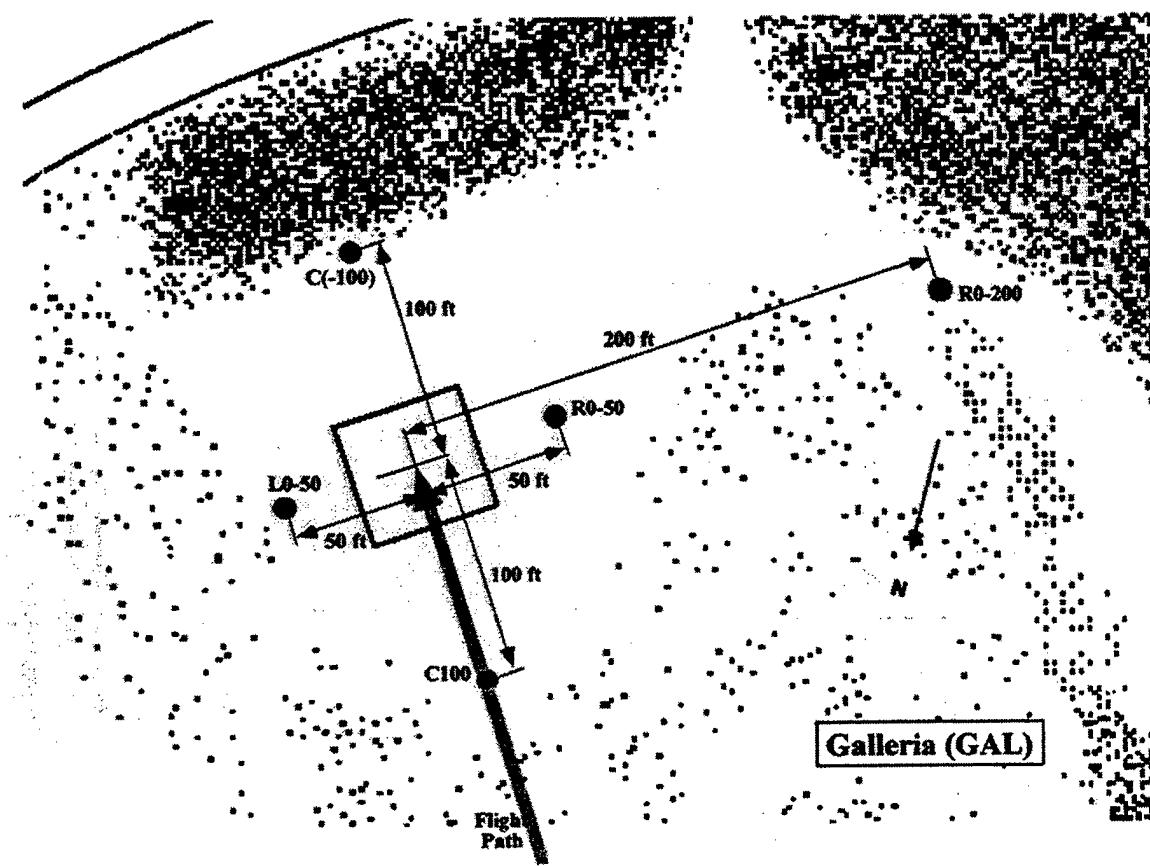


Figure 3.3 The acoustic measurement locations at the Galleria helipad site.

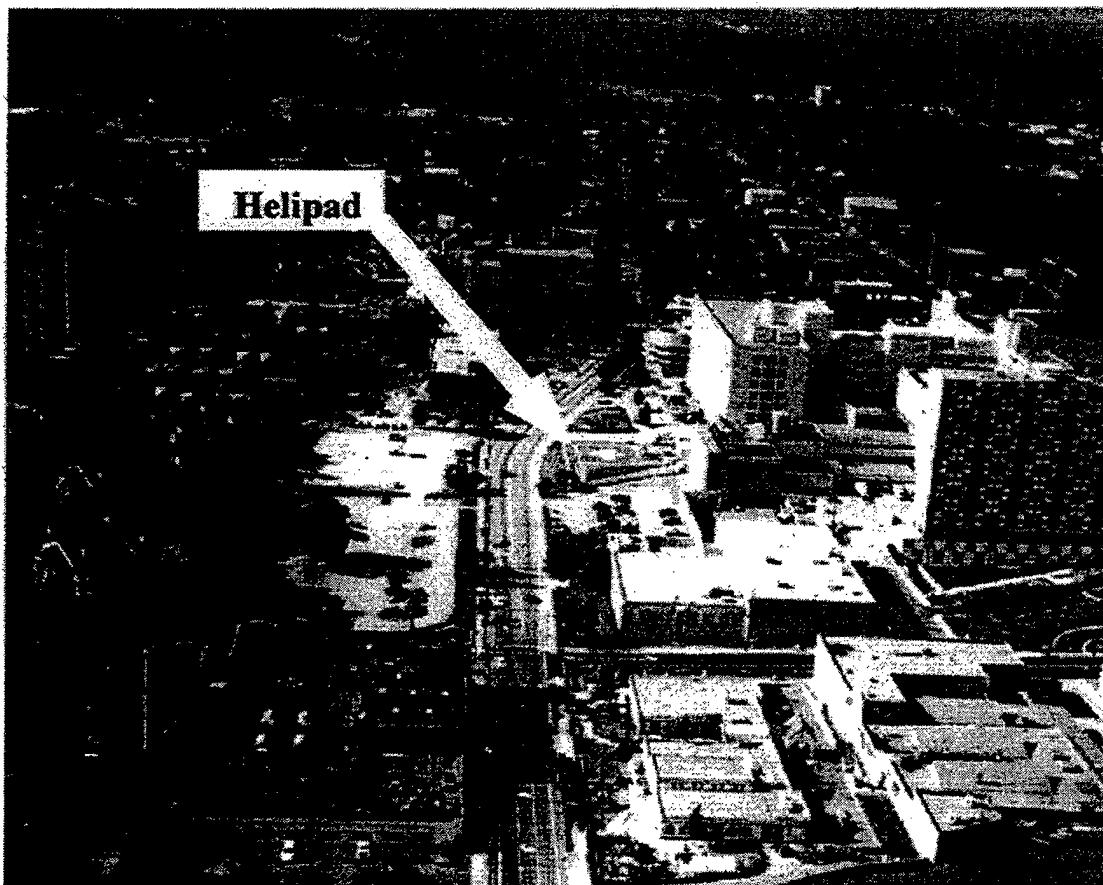


Figure 3.4 Aerial photograph of Georgia Baptist Hospital helipad (GBH) and its surrounding area.

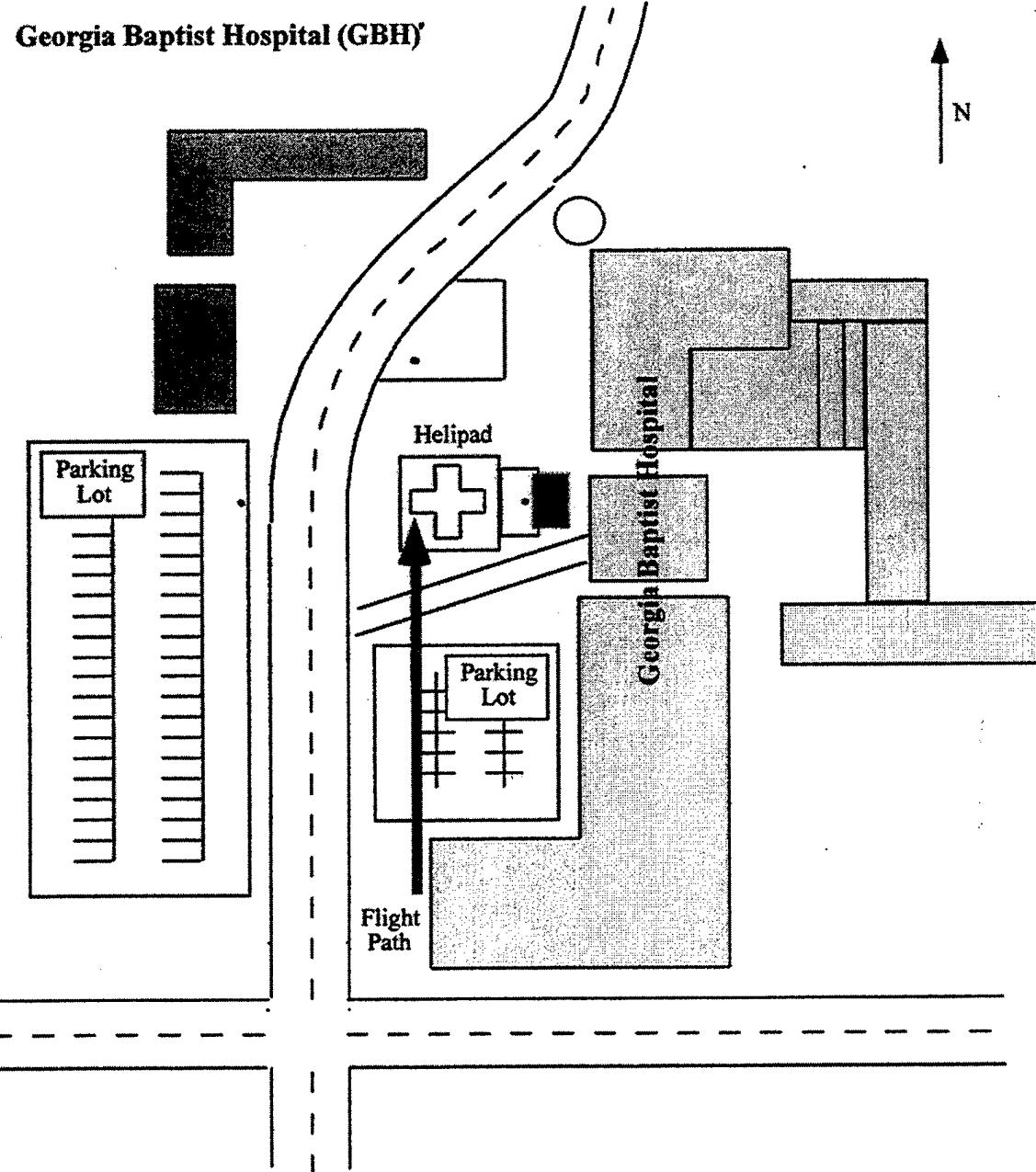


Figure 3.5 A map of Georgia Baptist Hospital helipad and the immediate surrounding area.

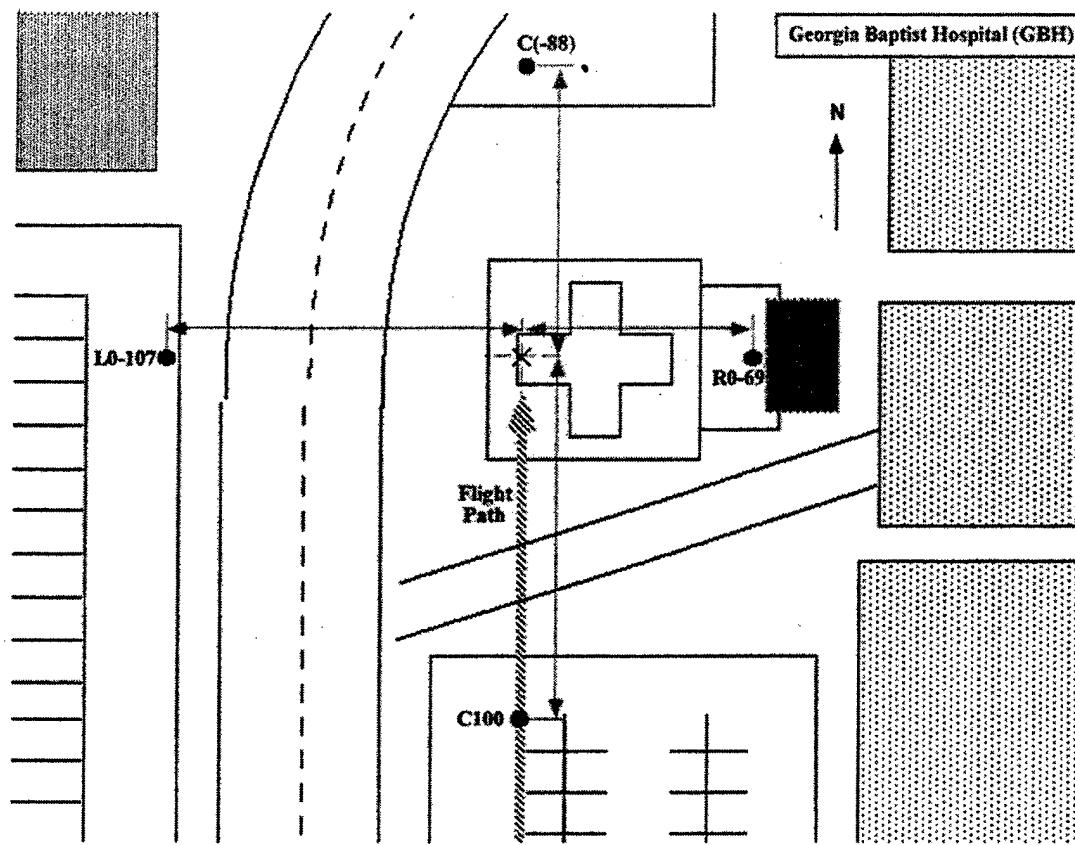


Figure 3.6 The acoustic measurement locations at Georgia Baptist Hospital helipad site.

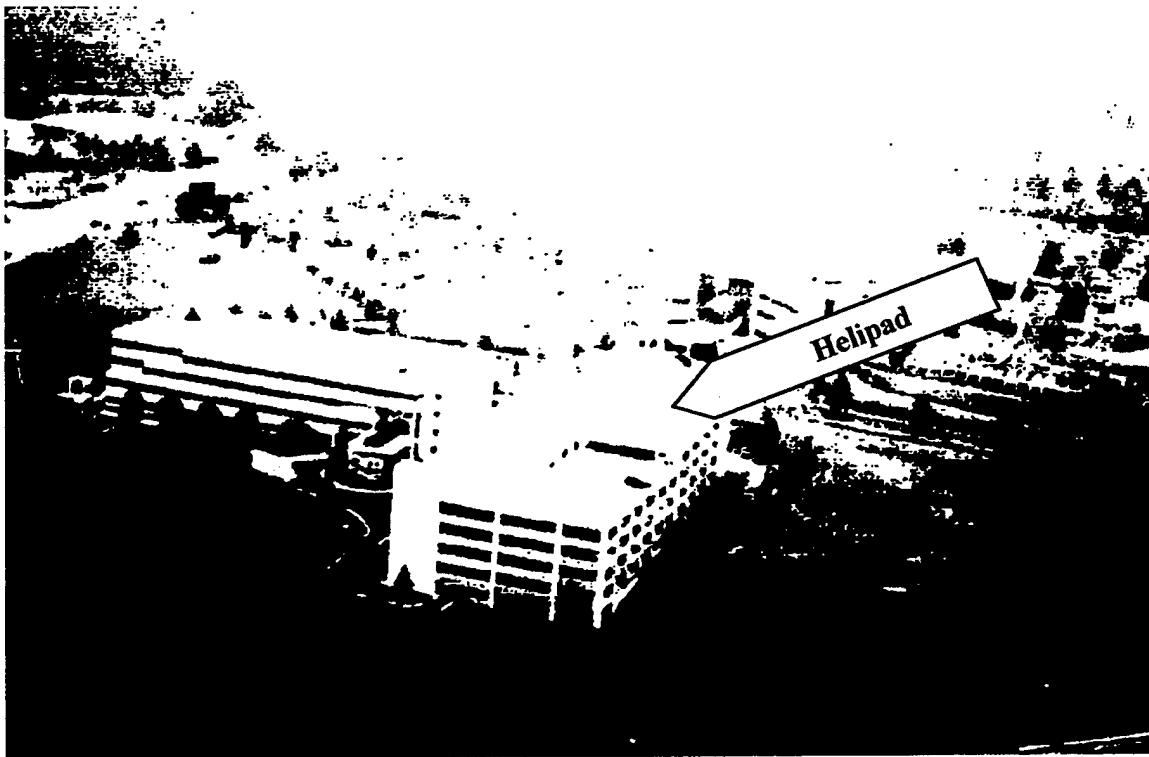


Figure 3.7 Aerial photograph of North Fulton County Hospital helipad (RAF) and its surrounding area.

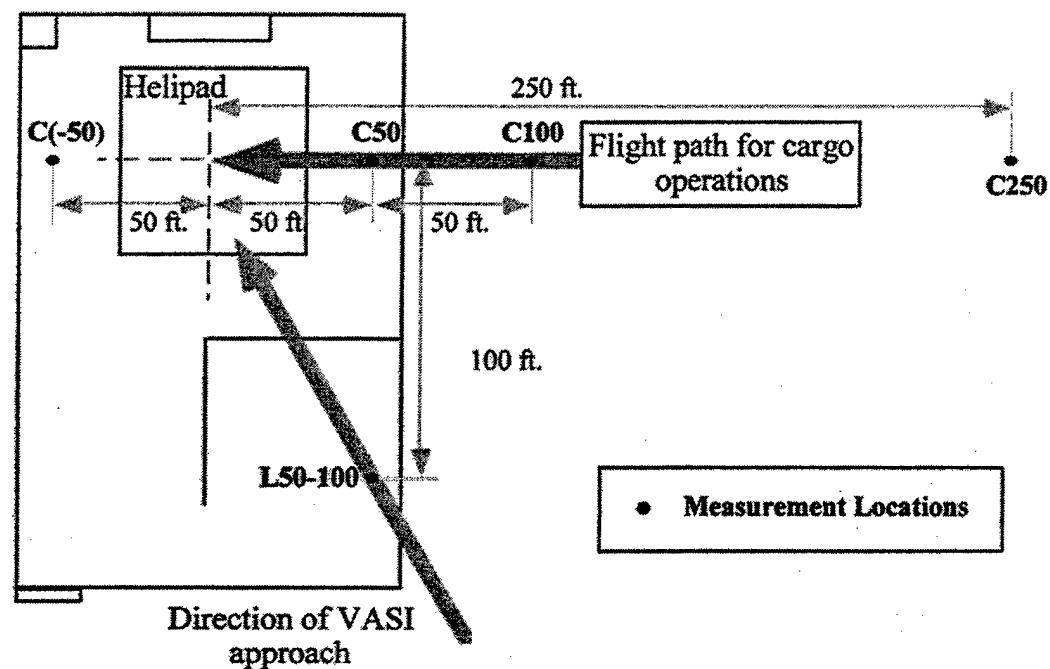


Figure 3.8 A map of North Fulton County Hospital helipad and the acoustic measurement locations at this helipad site.

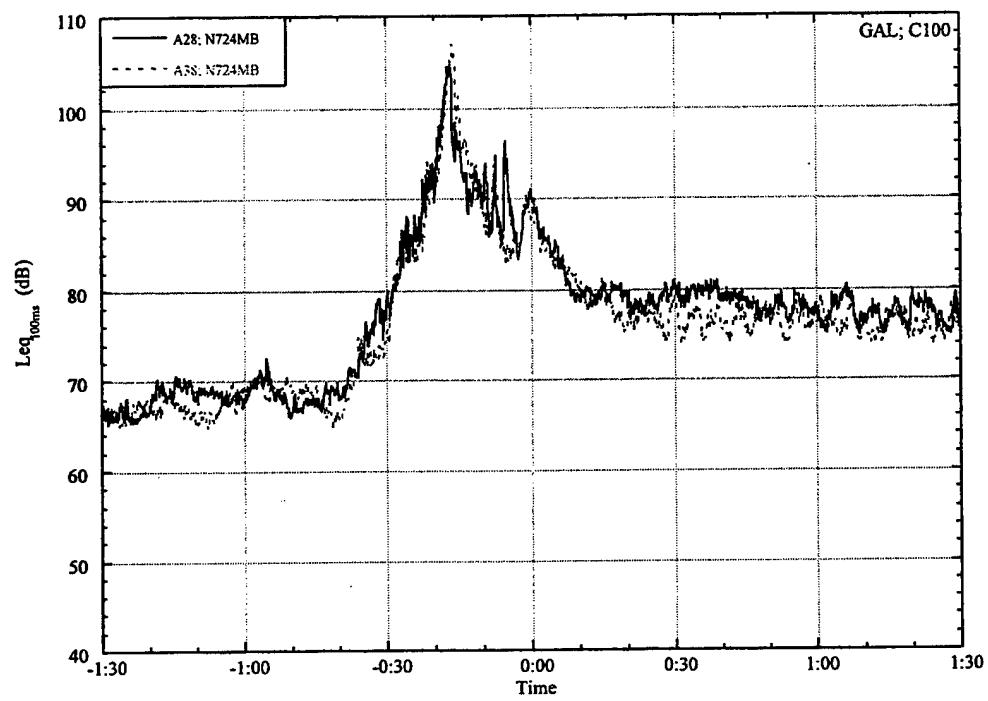


Figure 4.1 100 ms Leq acquired at Galleria helipad for flight A28 and A38.
(Measurement location: underneath flight path, 100 ft away from the landing point;
Helicopter: N724MB, BO-105).

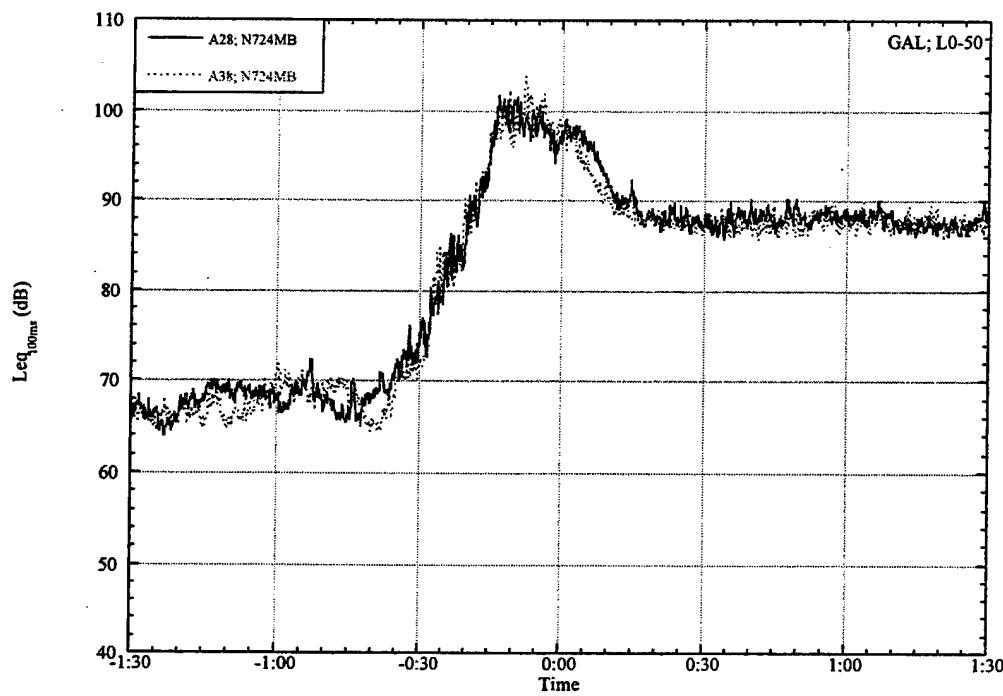


Figure 4.2 100 ms Leq acquired at Galleria helipad for flight A28 and A38
(Measurement location: 50 ft. to the left of the helipad. Helicopter: N724MB, BO-105)

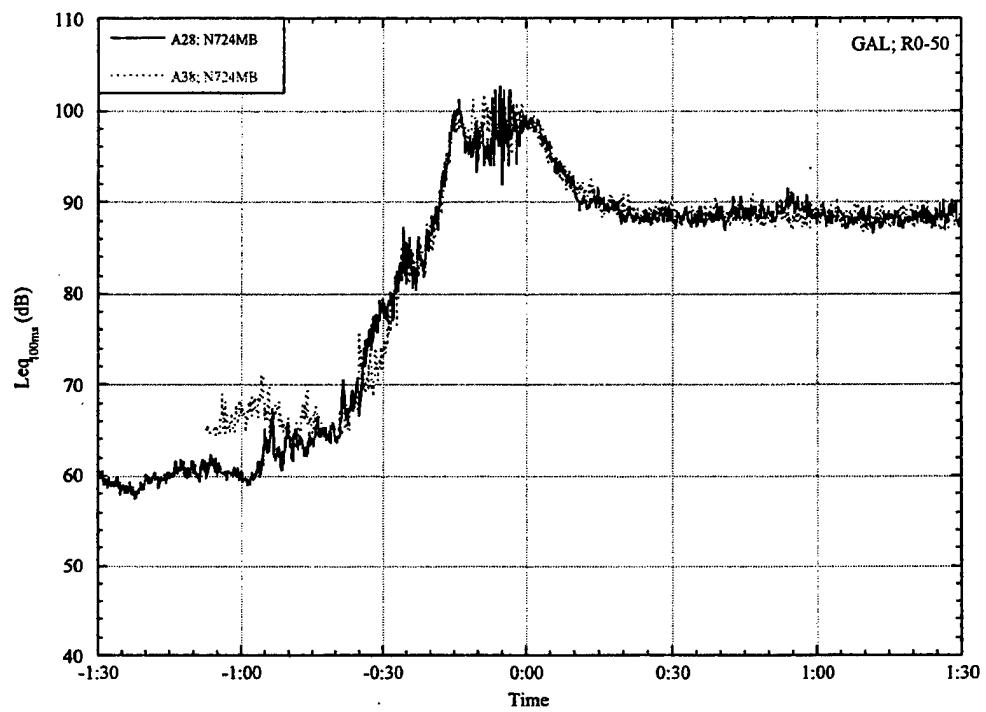


Figure 4.3 100 ms Leq acquired at Galleria helipad for flight A28 and A38
(Measurement location: 50 ft. to the right of the helipad. Helicopter: N724MB, BO-105).

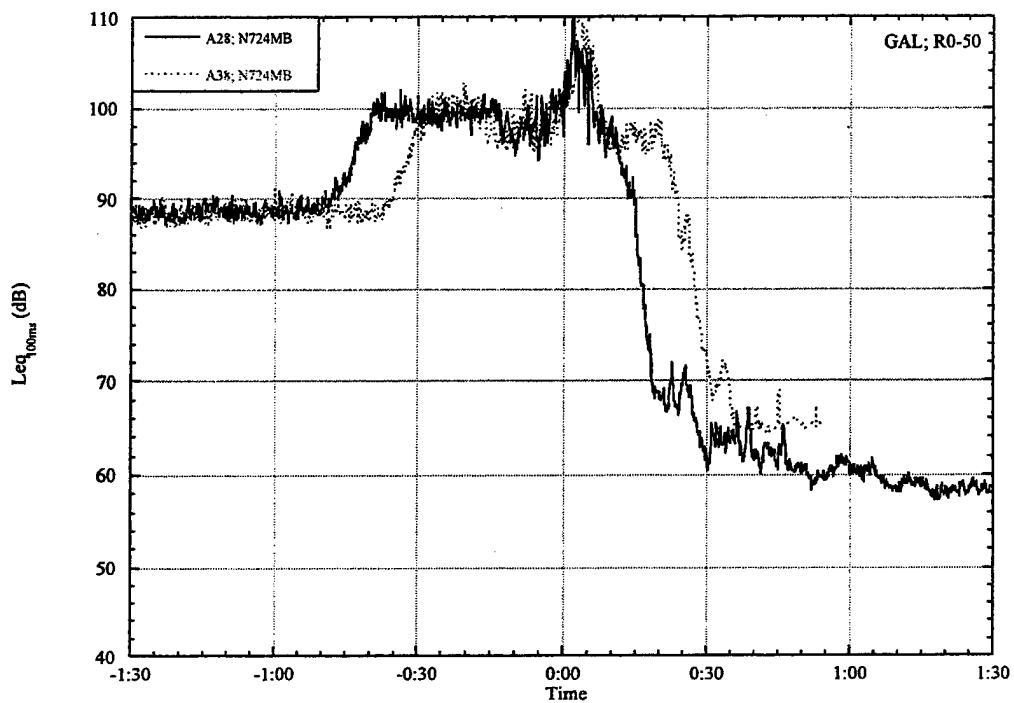


Figure 4.4 100 ms Leq acquired at Galleria helipad for flight A28 and A38
(Measurement location: 50 ft. to the right of the helipad. Helicopter: N724MB, BO-105).

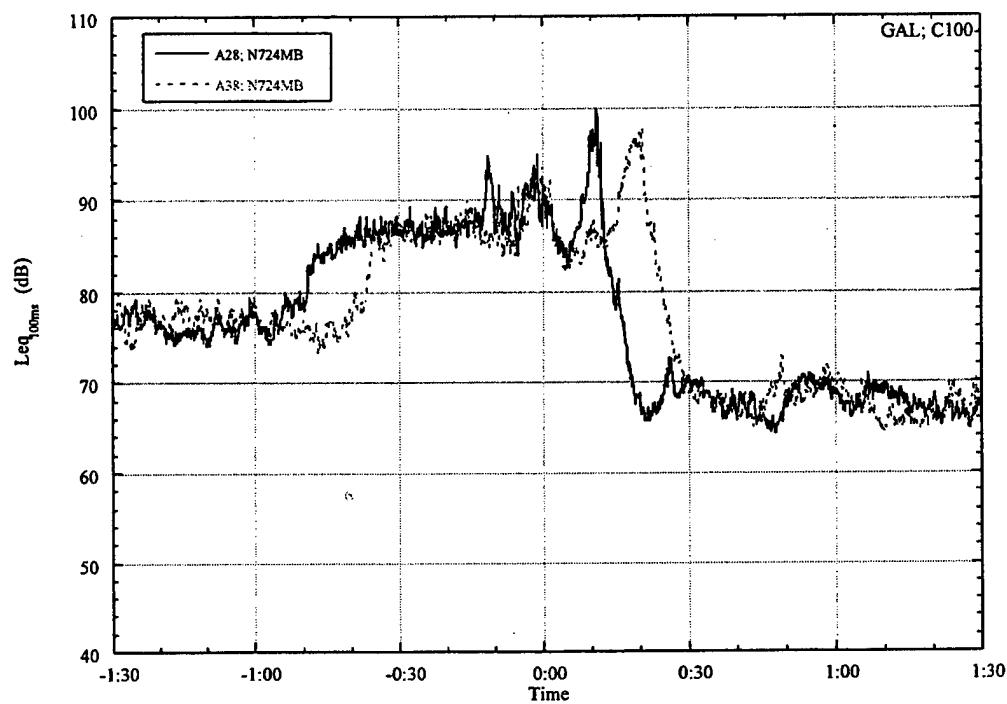


Figure 4.5 100 ms Leq acquired at Galleria helipad for flight A28 and A38
(Measurement location: underneath flight path, 100 ft away from the landing point;
Helicopter: N724MB, BO-105)

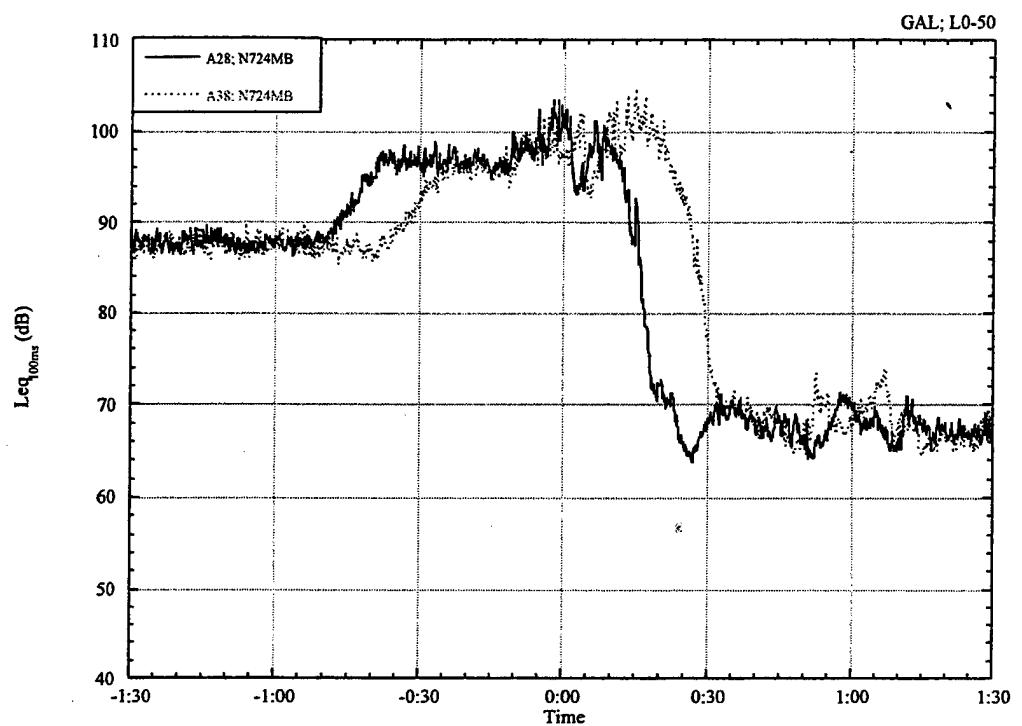


Figure 4.6 100 ms Leq acquired at Galleria helipad for flight A28 and A38
 (Measurement location: 50 ft. to the left of the helipad. Helicopter: N724MB, BO-105)

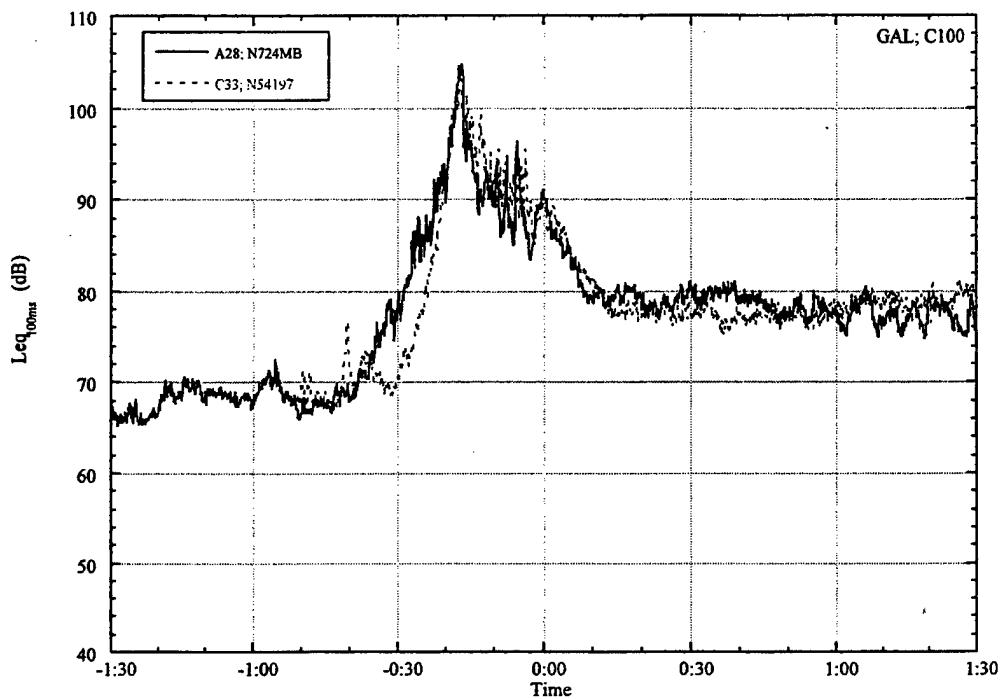


Figure 4.7 100 ms Leq acquired at Galleria helipad for flight A28 and C33
 (Measurement location: underneath flight path, 100 ft away from the landing point;
 Helicopter: N724MB, N54197)

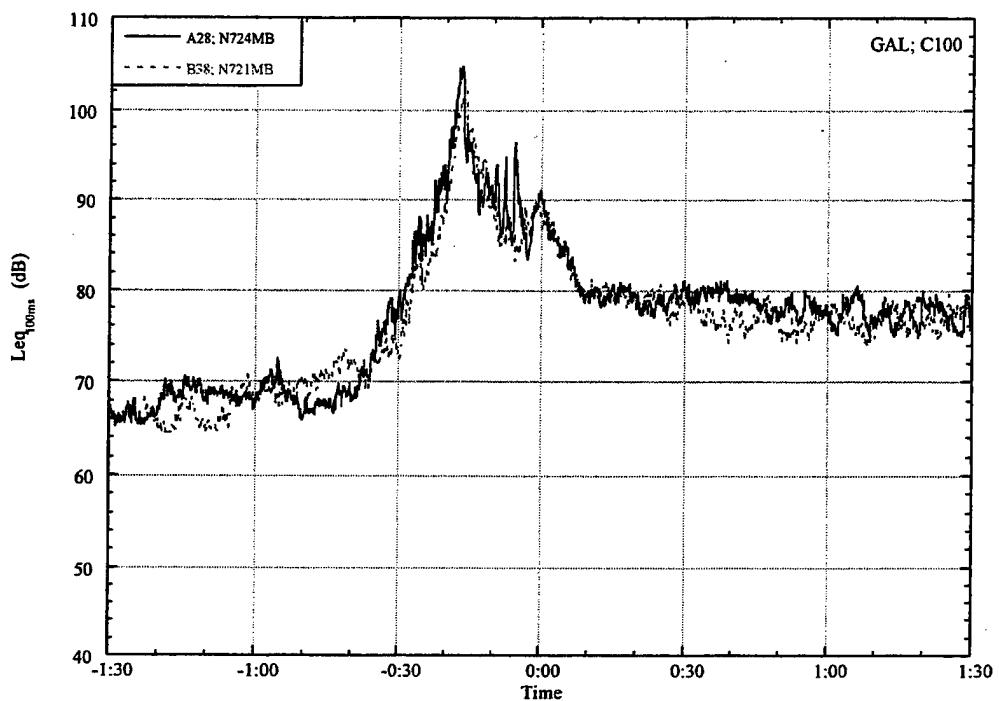


Figure 4.8 100 ms Leq acquired at Galleria helipad for flight A28 and B38
(Measurement location: underneath flight path, 100 ft away from the landing point;
Helicopter: N724MB, N54197)

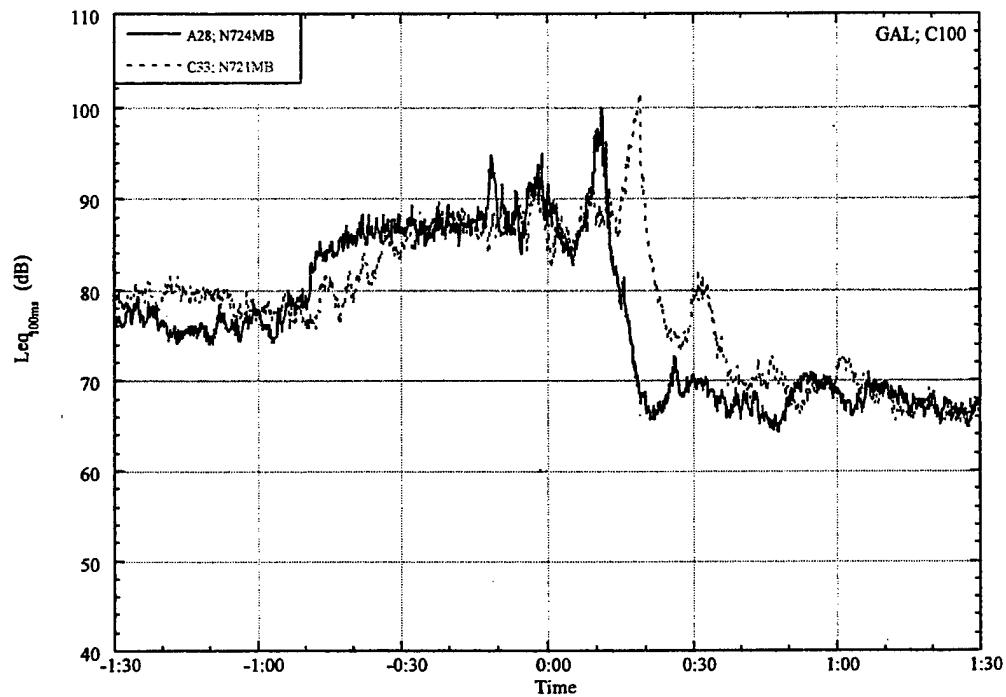


Figure 4.9 100 ms Leq acquired at Galleria helipad for flight A28 and C33
(Measurement location: underneath flight path, 100 ft away from the landing point;
Helicopter: N724MB, N54197)

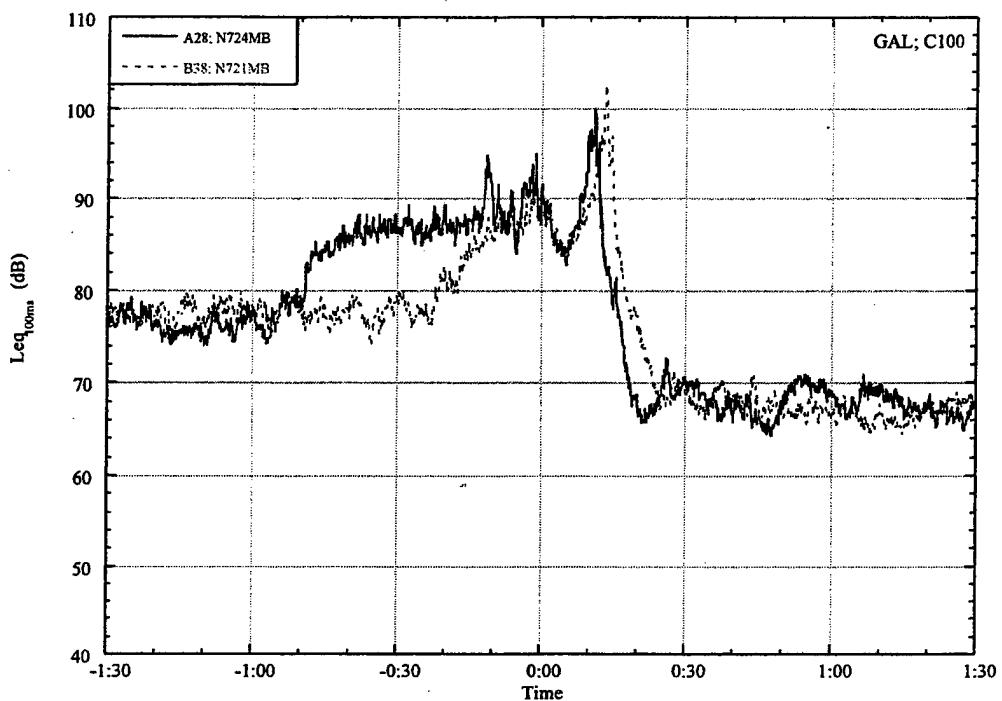


Figure 4.10 100 ms Leq acquired at Galleria helipad for flight A28 and B38
 (Measurement location: underneath flight path, 100 ft away from the landing point;
 Helicopter: N724MB, N721MB)

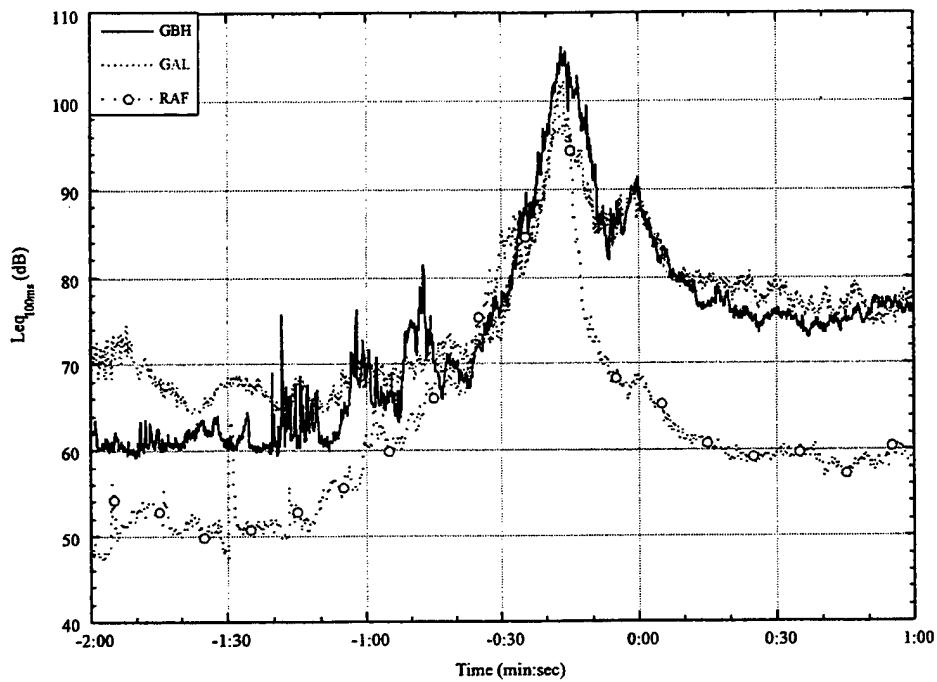


Figure 4.11 100 ms Leq acquired at three different helipad sites (Measurement location: underneath flight path, 100 ft away from the landing point; Helicopter: N721MB, BO-105)

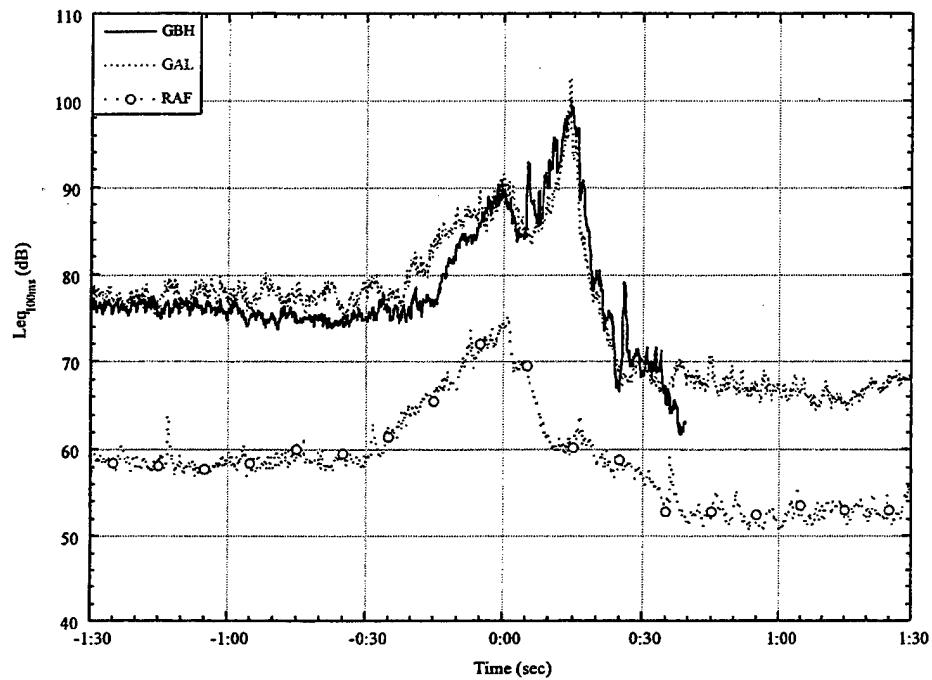


Figure 4.12 100 ms Leq acquired at three different helipad sites (Measurement location: underneath flight path, 100 ft away from the landing point; Helicopter: N721MB, BO-105)